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THE X-SAR SYSTEM

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I. INTRODUCTION

During the past few years, there has been significant progress made in the planning for an X-band SAR /1/, designed to fly in the shuttle together with the SIR-C system of NASA/JPL. New work and studies have been initiated to enable the goal of two missions in 1990 to be met.

The antennas of X-SAR and SIR-C will be placed side-by-side on a pivoted steerable foldable structure, which will allow antenna movement without changing the attitude of the shuttle (fig. 1). This figure also shows the pallet, underneath the antenna structure, which houses the electronic sub-systems of both radars. Although the two radar systems, X-band SAR and the L- and C-band SAR of SIR-C, have different technical designs /2,3/, their overall system performance, in terms of image quality, is expected to be similar.

This paper details the current predicted performance of the X-SAR system based on results of the continuing Phase B studies /2/. Differences between the performance parameters of X-SAR and those of SIR-C are only detailed in as far as they affect planning decisions to be made by experimenters.

The X-SAR system is a joint German/Italian project, financially supported by BMFT/DFVLR[1] in Germany and PSN[1] in Italy. Project Scientists are Dr. Herwig Öttl on the German side and Prof. Francesco Valdoni on the Italian side. The role of the Project Scientist is to assist in optimizing the system performance to the scientific requirements subject to tight funding constraints.

II. KEY X-SAR SPECIFICATIONS

The shuttle is a unique space vehicle capable of fulfilling many varying requirements for differing experiments. Nevertheless, spaceborne radars have such high power requirements and generate very large data rates, which tax even the shuttle's resources. The combined X-SAR/SIR-C equipment will fully use the available on-board power (X-SAR alone uses 1.4 kW) and one radar channel will be sufficient to fully occupy the data transmitting capability of approx. 46 Mbits/s. Data from the other radar channels will have to be stored on tape on-board.

[1]BMFT = Ministry for Research and Technology.
DFVLR = German Aerospace Research Agency.
PSN = National Space Plan (Agency).

The constraints of power, bandwidth and physical size of the cargo-bay, together with a desire to have a large swath width of up to 50 km or more, dictated the following specifications:

Frequency	9.6 GHz
Polarization (transmit/receive)	vertical/vertical
Geometric resolution	ca. 25 m in azimuth (4 looks) and range
Swath width	10 km - 45 km
Radiometric resolution /4/	2.5 dB at $\sigma° = -18$ dB (4 looks) with 6 bit I / 6 bit Q quantization[2]
Off-nadir angle	15° - 60°

The predicted performance changes with the off-nadir angle and is derived in the following section.

It should be noted that X-SAR does not have the multi-polarization capability of SIR-C and that the X-SAR antenna (12 x 0.4 m) has a fixed beamwidth of 5.8° in elevation and 0.13° in azimuth, whereas SIR-C has a phased array antenna. A phased array antenna which permits the beamwidth to be changed, allows the swath coverage to be selected. There is a trade-off between swath width and resolution due to data rate limitations in the datalink or the on-board recorder. The X-SAR antenna has a gain >43 dBi.

III. EXPECTED PERFORMANCE

The high power amplifier is designed to generate more than 3 kW peak power. The low noise amplifier is expected to have a noise figure of less than 2 dB. A dynamic range window of 20 dB, adjustable in 2 dB steps (gain setting), can be selected from the 60 dB receiver dynamic available.

The Pulse Repetition Frequency (PRF) is variable in 16 steps between 1234 Hz and 1802 Hz. The exact setting depends on the shuttle configuration, orbit height (nominal 255 km) and off-nadir angle, and is chosen to minimize range ambiguity effects. The transmitted pulse has a linear chirp of length 40 µs and a bandwidth of 19 MHz or 12 MHz.[3] These bandwidths give slant range resolutions of 10 m and 16 m respectively.

Figure 2 shows some of the more important system parameters. The top four curves in the upper half of the figure give the swath width as a function of off-nadir angle, resolution mode, and radiometric resolution. The swath width is constrained by the elevation beamwidth at low off-nadir angles and by the data rate at high off-nadir angles. Note here that the high resolution modes refer to the 10 m slant range resolution case.

[2] 4 bit I/4 bit quantization is also possible.
[3] This may be changed to 19 MHz and 9.5 MHz, the figures planned for SIR-C.

The range ambiguity level, represented by the curve in the lower part of fig. 2, has been derived using the following assumptions:

- the antenna sidelobes in elevation are at least 20 dB below the mainlobe,

- σ° is constant across the whole elevation pattern.

The ambiguity level is calculated as the ratio of the desired reflected signal within one range bin to the sum of all extraneous reflections whose returns lie within the same range bin or time interval.

The bounds on the system sensitivity area, also shown in the lower part of fig. 2, are given by the two radiometric resolution values of 2.5 dB and 3 dB and the illuminated swath width.

It should be noted that a 3 dB margin, to cover possible additional losses arising in the X-SAR design and construction stage, has been included in fig. 2 whose figures, in any case, represent conservative values.

IV. CALIBRATION, SURVEY PROCESSOR

As part of the internal calibration philosophy of X-SAR, it is planned to monitor the phase and amplitude stability of the chirp by passing a replica of the transmitted pulse through the receiving chain. Distortions introduced by the High Power Amplifier, such as a amplitude ripple, are measured separately.

Parallel to the X-SAR sensor itself, a real-time survey processor is also being developed. This processor will be used to verify system performance, for quick look processing during the mission, and in selecting the scenes for full precision processing.

V. SCIENTIFIC GOALS

A summary of the prime scientific objectives of the X-SAR mission, in both land and sea applications, is given in /5/.

Experiments will be selected by Spring 1987, based on the response to the announcement of opportunity due to be issued shortly. The mission planning will then be tailored to the selected experiments.

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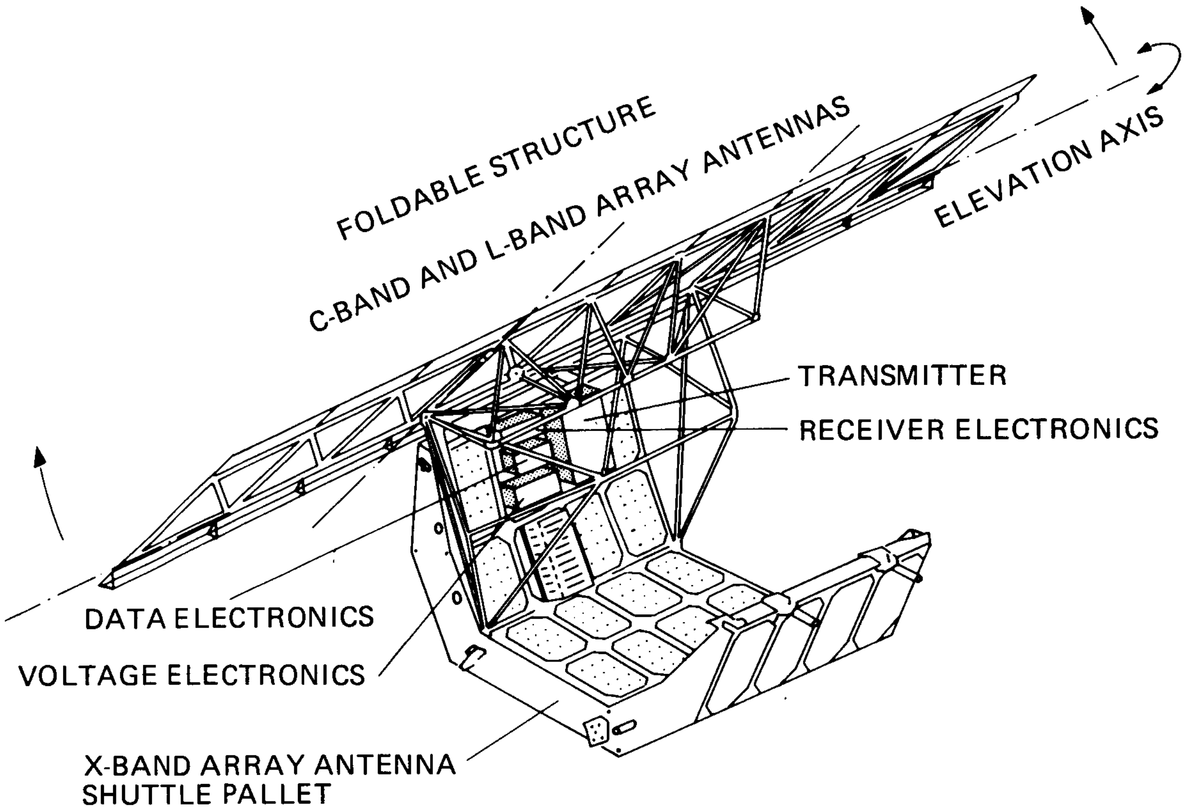

Figure 1. X-band, C-band and L-band antenna mounted above the shuttle structure. Only the containers for X-SAR electronics are shown.

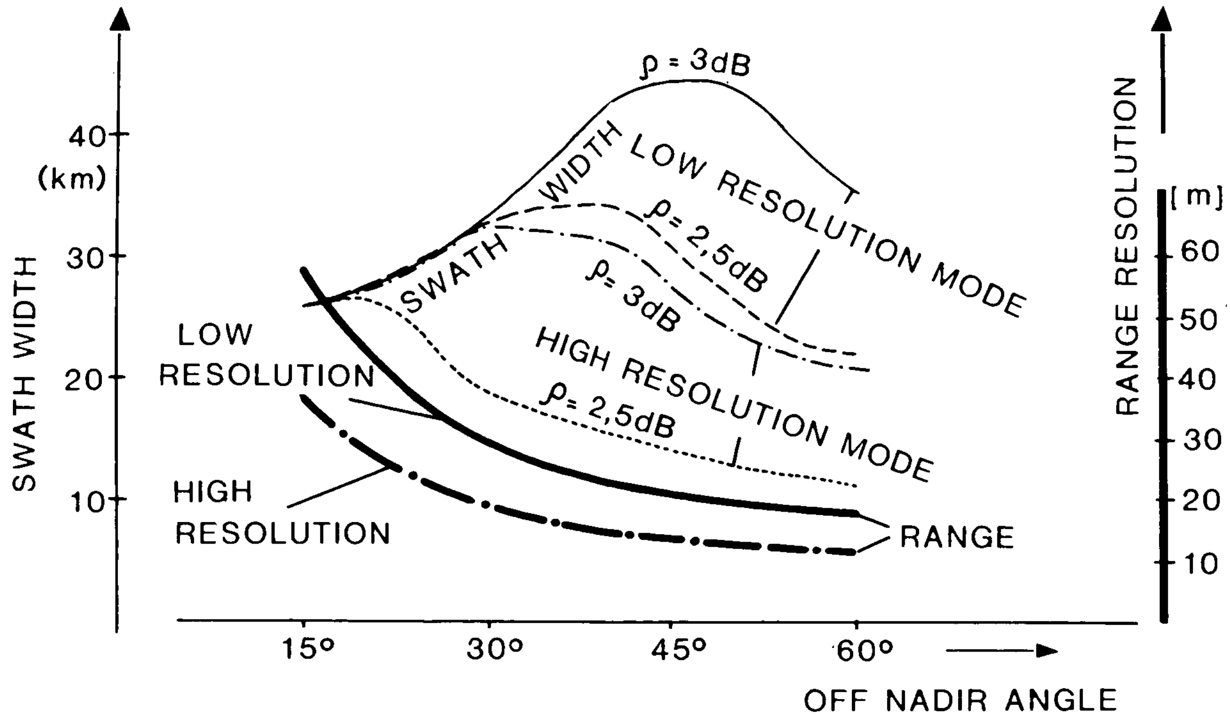

Figure 2a. Swath width and range resolution.

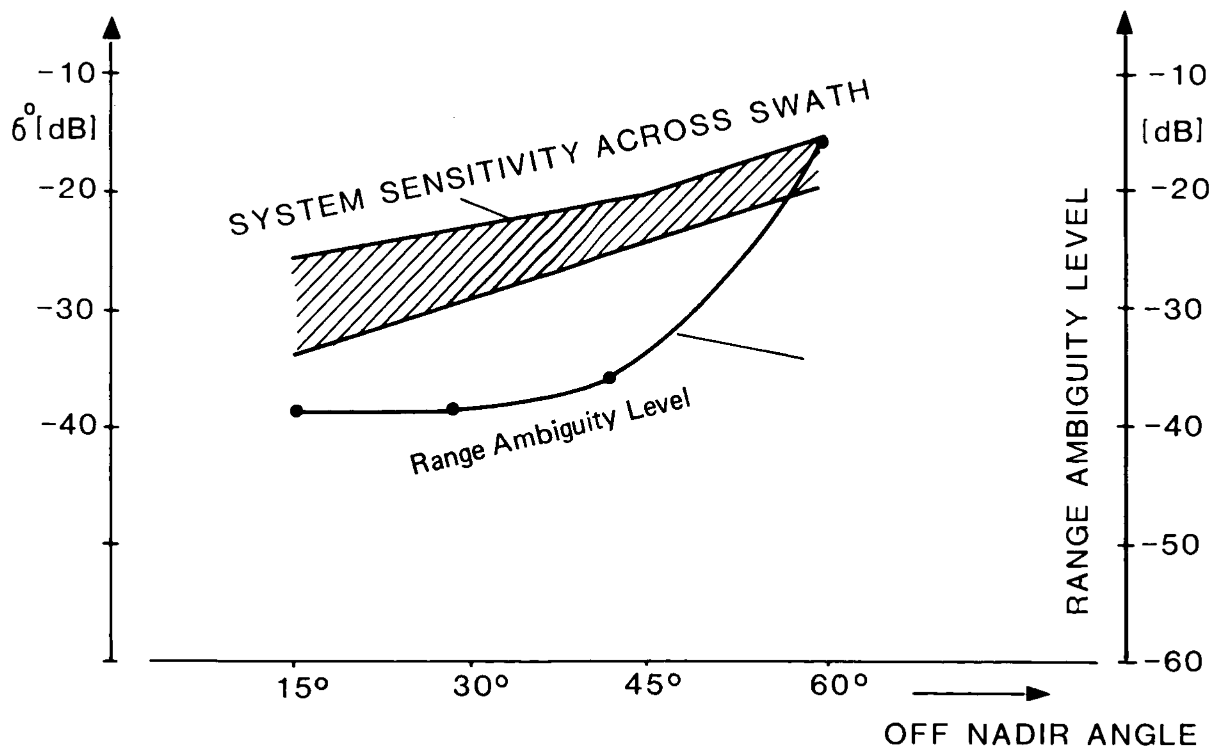

Figure 2b. System sensitivity and range ambiguity level.